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How important is heterogeneous parameter distribution in capturing the catchment response through hydrologic modelling?

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The scrupulous selection of critical spatial and temporal resolution and the evaluation of optimum values for various model parameters are essential aspects in any hydrological modelling study. The accurate assessment of various model parameters is vitally important for the detailed and complete representation of the various physical processes illustrating land-atmosphere interaction. Studies in the past have taken up various auto-calibration and parameter transferability schemes to address these; but the heterogeneity of calibration parameters across grids is greatly ignored often. In many studies, heterogeneity is often compromised through the usual interpolation approaches adopted across grids. In the present study, we focus to analyze the response of a catchment by adopting a heterogeneous and homogeneous parameter distribution in the hydrological model. The semi-distributed hydrological model, Variable Infiltration Capacity (VIC-3L) model, which offers sub-grid variability in soil moisture storage capacity and vegetation classes, is used for this comparison. Nine model parameters are selected for calibrating the VIC-3L model, namely variable infiltration curve parameter (infilt), maximum velocity of base flow for each grid cells (DSmax), fraction of DSmax where non-linear base flow begins (DS, fraction of maximum soil moisture where non-linear base flow occurs (WS), depth of 2nd soil layer (D2), depth of 3rd soil layer (D3), exponent used in baseflow curve (c), advection coefficient (C) and diffusion coefficient (D). Latin-Hypercube sampling is adopted to sample these nine parameters. In homogenous approach, the traditional way of constant soil parameter distribution (HoSCP) is adopted to prepare the parameter set. While, in heterogeneous approach, grid-to-grid variability is ensured by constructing a Heterogeneous Soil Calibration Parameter (HeSCP) set through systematic sampling of already sampled set. The sampling size is made equal to the number of grids falling inside the basin.
The performance analysis of HoSCP and HeSCP sets is done by developing the VIC model for Mahanadi basin, India, at two spatial (2° and 0.25°) and temporal (daily and monthly) resolutions. The model performance is analysed using various performance measures (NSE, RSR, R2 and PBIAS). Comparison of the annual flow patterns and the frequencies for both HeSCP and HoSCP sets, reveals that the finer resolution (0.25°) is more sensitive to the parameter distribution as compared to the coarse resolution (2°). HeSCP distribution captures annual cycle and frequencies better with relatively low uncertainty, as compared to HoSCP set. The long-term averages simulated by HeSCP set only deviates from observed data by 93 cumecs while those simulated by HoSCP deviates by 338 cumecs. Further, parameter variability is analyzed by assessing wet (>90% of observed data) and dry (<10% of observed data) flows, which reveals that the percentage change in wettest annual flow by HeSCP set is 11% less than that by HoSCP set. Similarly, for driest annual flows, the difference is 31%. Hence, the study urges the need to capture the grid-to-grid parameter variability in hydrological modeling studies, especially when performed at finer resolutions. It is expected that the suggested framework will help to improve the performance of hydrological modelling studies in any region.
Keyword: Hydrological modelling, Auto-calibration, Parameter transferability, Heterogeneity, Semi-distributed model.